This result is the more remarkable in that up till now, in spite of innumerable attempts, no one has ever succeeded in making any animal whatever immune against tetanus. A theory of the nature of acquired immunity which at once led to a method of treating the disease which is easy to understand, harmless to the animal, and certain in its effect, must surely possess some basis in fact.

Naturally every kind of control experiment with serum of normal rabbits has been carried out with uniformly negative results. Serum of cattle, horses, and sheep has also been found to have no action on the tetanus poison. The living blood and tissues of an animal which has not been made immune likewise show no power of destroying the tetanus poison, as appears from the following experiment, which has been many times repeated:—

Rabbits into which 0·5 c.c. of a germ-free tetanus culture is injected subcutaneously, succumb after showing typical tetanus symptoms; almost always a serous transudation is to be found in the thoracic cavity. Of this transudation, 0·3 c.c. is on the average enough to kill a mouse with typical tetanus symptoms. The same is true for the blood.

The authors close their paper by pointing out the possibility that their method of curing tetanus and diphtheria which they have used with such brilliant results on animals so highly susceptible to these diseases as mice and rabbits, may also be used for the far less susceptible hospital patient. They also note the possible influence of their work on the practice of blood-transfusion.

E. H. HANKIN.

THE STEAM-ENGINE.

The Steam-Engine considered as a Thermodynamic Engine. A Treatise on the Thermodynamic Efficiency of Steam-Engines, illustrated by Diagrams, Tables, and Examples from Practice. By James H. Cotterill, M.A., F.R.S., Professor of Applied Mechanics in the Royal Naval College. Second Edition, revised and enlarged. (London: E. and F. N. Spon, 1890.)

IN view of the general interest attaching to the recent improvements in steam-engines, and the consequent gain so remarkably illustrated by the increased speeds of ocean travel, an exposition from a purely scientific point of view of the causes of this progress comes at a very opportune time. The book before us is the second edition of a treatise which was originally published in the year 1877, and has since that time remained one of the chief authorities on the practical applications of thermodynamics.

It seems to be inherent in the industrial development of scientific laws that the course of invention should occasionally lead engineers away from the principles of pure science on which their work is based. The minds of inventors often become so much occupied with the intricate and perplexing problems presented by the mechanical realization of their ideas, that in the specifications of their successful arrangements, the naked principles which are the common and essential part of all practice are sunk far beneath the surface. It is of no ordinary importance that means should exist for co-ordinating the two independent growths of knowledge which are thus indicated. Probably no more weighty or influential calling exists for the industrial progress of the nation than that of the scientific engineers who are able to take into their view both sides of this field, and lead to the fertilization of each by the results of the other.

The progress of the science of heat forms one of the most interesting chapters in scientific history, and illustrates in a remarkable manner the way in which conceptions that at the time of their development appear of the most advanced and recondite character become the common elementary ideas of succeeding generations. The first great advance was no doubt the introduction of precision into the measurement of temperature by the invention of thermometers, and of the method of graduating them by first marking the fixed points on their scales. As Dr. Gamgee has recently pointed out, in a paper read before the Cambridge Philosophical Society, the fixed points by means of which Fahrenheit graduated his original alcohol thermometers were hardly physical at all; the higher one was the temperature of the armpit or mouth of a healthy man, which he had observed to be constant. It was after the Fahrenheit scale had been fixed by this temperature and that of the best available frigorific solution (snow and salt) that the construction for the first time of a mercury thermometer gave an opportunity of testing the boiling-point of water, which in this way was found to be constant, and under standard conditions to be at the point marked 212° on the scale. It was not until near our own time that the possession of methods of thermometry, combined with the researches of Black and others on the transfer and latency of heat, led, under the influence of Davy, Mayer, and Joule (and also Carnot), to the recognition of heat as a form of energy, and made possible an exact study of its transformations.

The final stage in the dynamical specification of the subject arrived when the very remarkable generalization of Carnot led, in Sir W. Thomson's hands, to a purely physical definition of a temperature scale, and the experiments of Joule and Thomson established the very close approximation of this scale to that of an ordinary thermometer, formed with one of the more permanent gases as expanding substance. This temperature scale enters into the general entropy equation employed by Clausius to express mathematically the results of Carnot's principle; so that in this form temperature has virtually a definition in analytical dynamics, and is an essential element in any dynamical theory which attempts to explain the phenomena of heat-transformation. These topics, treated in the simpler cases, now form a part of every course of physics.

The entropy formula expresses a relation between the initial and final states of the system, which is independent of the path of transition from the one to the other, provided this path be reversible. It is, therefore, to be classified with the fundamental dynamical investigations of Sir W. Rowan Hamilton, whose principal function is expressed in terms of the initial and final positions of the system, and the energy contained in it. It thus becomes a question of pure dynamics to inquire whether the entropy relation may be postulated as a general property of all motions, or whether its truth is constituted by the

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process of averaging the motions which is found essential to the development of the dynamical theory in the cases now in part unravelled, as, for instance, the kinetic theory of gases. In these discussions the chief difficulty is the dynamical realization and interpretation of temperature, as it is defined by its occurrence in the equation of entropy.

The nature of the difficulty is more fully realized when the fact is recognized that in a dynamical system, involving no dissipation of its energy to other systems, an exact reversal of the motions of all its molecular parts would cause it to retrace its original path, and would therefore reverse any degradation of energy in the thermodynamic sense that may have occurred in it. Thus, not merely is it possible for the thermodynamic order of Nature to be reversed by a continuous expenditure of intelligence without expenditure of energy, as in the case of the demons introduced by Clerk Maxwell into the exposition of the theory of gases; but a system may actually be put into such an initial state that it will go on reversing the laws of entropy of its own accord.

It is true that we are saved from the necessity of having to admit that such exceptions to the course of Nature may be actually existent; for all transfers of heat are inextricably mixed up with the phenomena of radiation, which involve transport of energy through the ether with a velocity the same as that of light, and which, therefore, require that if our system is to be absolutely conservative it must include the ether and extend beyond the farthest star. In any portion of a system thus constituted, however we may suppose degradation staved off and reversed by a complete reversal of its motions, the effect produced will be only temporary, and degradation will ultimately reassert itself.

Nevertheless, the problem remains for solution, how far the law of entropy, whose truth in a limited range is demonstrated by the fact that it is fundamental to the wide and firmly established science of thermodynamics, is to be considered as a principle of a purely dynamical character; and although the investigations of Clausius, von Helmholtz, Boltzmann, J. J. Thomson, and other mathematicians who have attacked the subject, have thrown much light on its affinities to known analytical laws of pure dynamics applied to systems in a steady state of motion, yet it is not too much to hope that there is a great deal more to be gained in this department of investigation.

In particular, a theoretical basis has yet to be supplied to the applications of the law of entropy to purely chemical actions. The results of its application to voltaic phenomena by Willard Gibbs and von Helmholtz have met with satisfactory experimental confirmation; while its extension to the theory of osmotic phenomena, dissociation, and the whole field of the chemical action of dilute solutions seems to be at any rate in qualitative accordance with facts, and even promises to fundamentally modify some of our notions of chemical action.

And there yet remains for answer the question which has long been put, whether there is any reason to suppose that the activities of living animal (or plant) tissue are limited by the principle in the same way as are those of dead matter.

The fundamental character of the views opened up by the development of Carnot's ideas on the efficiency of heat-engines adds a strong theoretical interest to the manner in which engineering practice has approximated to its ideal conclusions. Even though their full and complete application in the domain of heat-engines would not be questioned by anyone, yet it is clear that the investigations that have arisen out of their experimental testing and improvement have much value as illustrations and models for similar inquiries in more abstract departments of physics. Indeed, the subsidiary discussions in this treatise, relating to causes of waste of available energy, remind one, on a magnified scale, of the corresponding corrections necessary in thermo-chemical investigations, particularly those relating to entropy; and there seems to be a considerable field in which the one subject may profit from a study of the other. In this connection the admirable arrangement, discussion, and analysis contained in the chapters on the causes of loss of efficiency supply a store of information and general principles that would not otherwise be easily available for non-professional workers.

It is unfortunate that the science of thermodynamics suffers more than any other department of physics from the difficulty of exact comparison between theory and experiment. It may be a surprise to some people to learn that even the value of the mechanical equivalent of heat is hardly certain within 1 per cent.: it appears that recent experiments by Rowland give a result nearer to 782, that derived by Joule from the electrical method, than to 772, the value finally put forward by him from the results of several concordant series of direct experiments.

The treatise which has suggested these remarks contains a connected account of the different ways in which thermodynamic theory has been applied and realized, the subjects treated and co-ordinated ranging over air-engines, gas-engines, guns or powder-engines, reversed air-engines or refrigerators, and, in greatest detail of course, the different types of steam-engine. The reader will find in it a simplicity in the statement of physical results, and a freedom from the encumbrances of algebraic analysis in the discussion of general laws, which form one of the highest merits of a treatise on the principles of natural philosophy, and the most fitting preliminary to the examination by mathematical analysis of special problems. This is combined with a very interesting account, illustrated by actual examples derived from recent practice, of progress made in actual construction towards the ideal of perfection, which it would be beyond our province to refer to in detail. From the point of view of the student of physics, the book forms a most valuable supplement and corrective to the necessarily abstract discussions which form the substance of treatises on theoretical thermodynamics.

J. LARMOR.

THE CLASSIFICATION OF ANIMALS.

Zoological Types and Classification. By W. E. Fothergill, M.A., B.Sc. (Edinburgh: James Thin, 1890.)

A Zoological Pocket-book or Synopsis of Animal Classification. By Emil Selenka and J. R. A. Davis, B.A. (London: C. Griffin and Co., 1890.)

THE author of the work bearing the first of the above titles has set himself a most formidable and ambitious task, viz. that of compressing into a small volume

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